Modification of the Entity State PDU for Use in the End-to-End Test

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ABSTRACT

The End-To-End Test (ETE) is being conducted under the auspices of the Department of Defense Joint Advanced Distributed Simulation (JADS) Joint Test and Evaluation (JT&E). The purpose of the ETE is to investigate the utility of using advanced distributed simulation (ADS) to augment both developmental and operational testing of the Joint STARS surveillance system. The basic concept behind the ETE is to augment the Joint STARS environment with a virtual environment created by thousands of simulated entities, or targets. This virtual environment is imaged by simulations of the radar systems contained within the Joint STARS E-8C aircraft and mixed with real radar returns to provide a robust operational environment for testing of the system.

The ETE Joint STARS simulation is called the Virtual Surveillance Target Attack Radar System (VSTARS). Simulated entities are transmitted to VSTARS through the use of Entity State Protocol Data Units (ESPDU). The simulation, or simulations, representing these entities transmit ESPDUs representing the status of each entity. This status is used to update data bases that are used to generate Joint STARS virtual radar images. Two modifications have been made to the ESPDU for use in the ETE. The first of these is a modification of the time field and is not mandatory, but is recommended. It records the time the ESPDU was created since the start of the simulation scenario. The second change to the ESPDU is performed internal to the Joint STARS simulation and is much more drastic. VSTARS must be capable of functioning anywhere needed, to include on board an aircraft during the conduct of a mission. This requires that the DIS network interface unit (NIU) for VSTARS exist in two parts, a ground NIU (GNIU) and an aircraft NIU (ANIU). The GNIU remains at a fixed location and receives ESPDUs from the DIS network. It then strips and modifies the ESPDU down to 192 bits of essential information and sends it to the ANIU. The ANIU performs the dead reckoning function and updates the data bases used to generate the virtual radar images. The ANIU resides in the same computer hosting VSTARS and may be found in a variety of locations such as a laboratory, on board the aircraft, or at a training site. This paper describes the modifications to the ESPDU and some of the reasons for the modifications. This procedure can be tailored for any sensor system that is not easily connected to a DIS network.

INTRODUCTION

The End-to-End Test (ETE) of the Joint Advanced Distributed Simulation (JADS) Joint Test Force (JTF) will evaluate the utility of using advanced distributed simulation (ADS) to complement the developmental and operational test and evaluation of a Command, Control, Communications, Computers, and Intelligence (C4I) system. The Joint STARS combination of E-8C aircraft and Ground Station was chosen as a representative C4I system on which to introduce ADS as a methodology in both DT&E and OT&E settings.

Joint STARS provides commanders access to near real-time radar imagery data in support of targeting decisions. The E-8C aircraft radar looks deep into hostile areas to detect, locate, classify, and track thousands of potential targets. This radar operates in two basic radar modes: moving target indicator (MTI) and synthetic aperture radar (SAR). MTI is capable of displaying the position of moving ground vehicles. SAR can provide images of both moving and nonmoving targets and of terrain and cultural features.

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Previous C4I system testing has exhibited shortfalls in providing adequate numbers of forces, friendly or enemy, to realistically portray an expected operational environment. ADS can generate a robust test environment by providing a more representative number of threats, plus the complementary suite of other C4I and the weapons systems that interact with a C4I system. Through a seamless mixing of live and virtual targets, the ETE will add thousands of additional entities to the few hundred available in peacetime battlefield exercises, and will better replicate a developed theater.

The ETE is a four-phase test. Phases 1 and 2 occur in a laboratory environment, suitable for exploring DT&E and early OT&E applications. Phase 3 checks compatibility of the ADS environment with the actual Joint STARS equipment. Phase 4 is an ADS-enhanced live open-air test linking a flying E-8C aircraft to actual ground station receivers, intelligence systems, fire control, and virtual shooters. A schematic of Phase 4 is shown below.

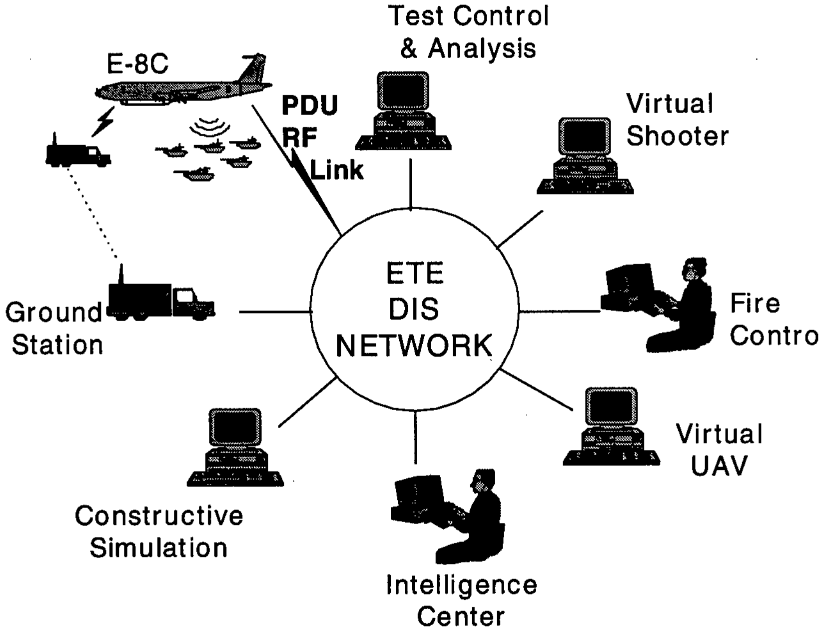

Figure 1. ETE Architecture

RF LIMITATIONS

In a typical DIS network, all simulation components are linked over local or wide-area ground-based networks. The ETE will link such ground networks, but also must include a flying aircraft receiving update information from a DIS network. This presents special challenges due to constraints on available radio frequency (RF) bandwidth between a ground transmitter and a receiver on board the aircraft. Current RF bandwidth available for the ETE is limited to around 19.2 kbps.

The current ETE network interfaces support a maximum of 100 ESPDUs per second. The DIS version 2.0.4 ESPDU contains 1152 bits of information (minimum), requiring a transmission rate of (1152)(100) $\doteq$ 115 kbps, much greater than the available bandwidth. Additionally, the E-8C aircraft provides an ESPDU denoting its existence and flight information on a 1 Hz update. This bandwidth discrepancy drove development of the modified ESPDU and network interface units used in the ETE.

ETE ARCHITECTURE

The VSTARS architecture receives ESPDUs from a DIS network through a ground network interface unit (GNIU), and transmits a modified PDU via an RF datalink to the corresponding air network interface unit (ANIU) aboard the flying aircraft.

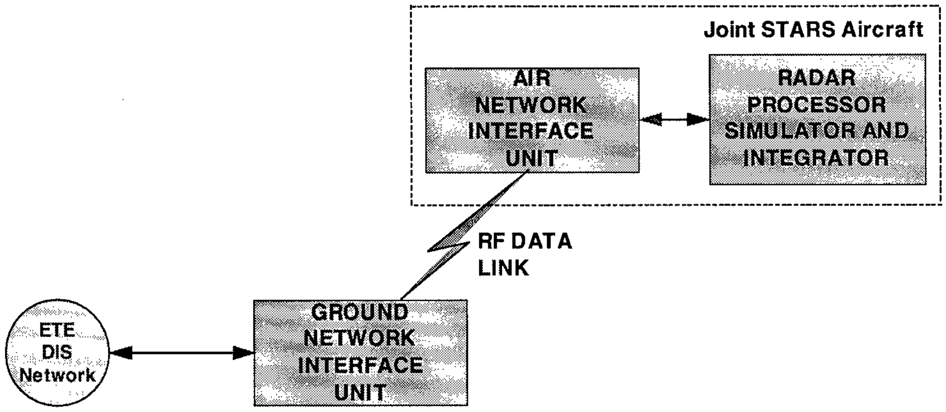

Figure 2: VSTARS Network Interface Units

NETWORK INTERFACE UNITS

The Ground Network Interface Unit first determines if arriving PDUs are Entity State PDUs. It then filters out those ESPDUs that are not within the E-8C simulation's area of interest. The remaining ESPDUs are stripped to a data packet containing the minimum information required to drive the MTI and SAR simulations in VSTARS. (This process is described later in this paper.) The GNIU converts location coordinates from DIS Earth-Centered-Earth-Fixed to the Topocentric Coordinate System used on-board the E-8C and in the RPSI. This conversion is done on the ground to save processing cycles onboard the aircraft. The GNIU then constructs an RF link message and transmits a stripped and modified data packet containing ground target information to the receiving ANIU.

The Air Network Interface Unit receives the incoming data packet and places the information in its target database. The ANIU performs dead reckoning on these targets, and updates the database based on its dead reckoning estimations and incoming target information. Dead reckoning is done on-board the aircraft to save RF transmission bandwidth from the GNIU. On request from the RPSI, the ANIU searches its database for those targets located in the appropriate ground location and provides such data to the RPSI SAR or MTI simulation.

Conversely, VSTARS provides to the ANIU data regarding the existence and location of the E-8C aircraft. The ANIU then composes and transmits a location data packet back to the GNIU denoting this information. The GNIU reforms the E-8C data into a DIS 2.0.4 ESPDU and broadcasts it to the DIS network.

ESPDU UPDATE MODIFICATIONS

DIS simulations normally send out ESPDUs on both a dead-reckoning update and a heartbeat basis. Dead-reckoning updates are sent whenever an entity location maintained in the simulation's internal location database exceeds by a given error parameter the locations maintained in some external DIS simulation database. Heartbeat ESPDUs are broadcast on a periodic basis (once every five seconds is recommended by the DIS standard) to permit simulations just entering the DIS network to initialize their databases, and also for those visual engines that require periodic updates.

The ETE simulation driver broadcasts dead-reckoning ESPDUs using the locational error parameters of the E-8C radar (i.e., radar CEP). This parameter can be decreased in the simulation software as necessary to account for latency in the ETE network. For example, assume the E-8C locational parameter error is 50 meters. A vehicle traveling at 5 meters / second can exceed the locational error in 5 seconds, necessitating an ESPDU update within 5 seconds. However, if network latency is 1 second, the dead-reckoning update must be shortened by at least 1 second (by adjustment of locational error parameter) for locational accuracy to remain within the aircraft radar CEP. Reducing the E-8C locational error parameter setting to 30 meters would require an ESPDU update in 3 seconds. On top of the 1 second latency, the updated ESPDU would arrive at a distant simulation in 4 seconds, which in effect is less than the radar CEP.

Between dead-reckoning updates, the ETE simulation driver broadcasts heartbeat ESPDU updates. Since the ETE network architecture and simulation participants are fixed prior to exercise initiation, no new players will join once the exercise begins; therefore, the newly entering simulation heartbeat requirement is eliminated. Also, none of the ETE visual engines require periodic updates. Were it not for the small chance of a non-mover being accidentally lost from the VSTARS database, this heartbeat could be eliminated. For VSTARS, the heartbeat is set initially and arbitrarily at a 10-minute update interval.

ETE ESPDUs arriving at VSTARS are maintained in a target database. Targets that are moving, or those stopping or starting, are updated as described above. Stationary targets are initialized in the database at exercise initiation. Once entered in the ANIU target database, targets are not routinely removed. Those targets that become battle-damaged or destroyed remain as burning hulks to be imaged by the E-8C SAR radar.

ESPDU DATA MODIFICATIONS

The VSTARS simulation driver need not provide the extensive target data available from the standard DIS ESPDU — information such as color, national origin, model, and so on is simply not visible to the E-8C radar sensor. This allows the ETE to strip such information from the ESPDU, and results in a smaller data packet that must be transmitted to the flying aircraft.

	Field Size ETE Modified ESPDU	
PDU Header	Time Stamp	32
Entity ID	Entity	16
Entity Type	Category	8
	Subcategory	8
	Specific	8
	Extra	8
Entity Linear Velocity	X-Component	16
	Y-Component	16
	Z-Component	16
Entity Location	X-Component	16
	Y-Component	16
	Z-Component	16
Entity Orientation	Psi	16
PDU Size		192 bits

Chart 1. ETE Modified ESPDU

- The VSTARS time stamp records the ESPDU creation time for up to 8 exercise hours, compared with the DIS protocol of restarting every hour. This is required by a normal 8 hour Joint STARS mission length.
- Entity Type contains the minimum information required for an overhead radar sensor as described above.
- Location data has been converted from Earth-Centered-Earth-Fixed to Topocentric Coordinate System and reduced to 16-bit accuracy, sufficient to remain within the error requirements of the E-8C radar.
- Likewise, velocity data has been reduced to 16-bit accuracy.
- Orientation is restricted to that visible to the E-8C radar in the radar slant plane.

Total Modified ESPDU size is 192 bits, compared with 1152 + 128n bits in the DIS 2.0.4 ESPDU.

		Field Size E-8C ESPDU
Header	Time stamp	32
E-8C Location	X-Component	32
	Y-Component	32
	Z-Component	32
E-8C Velocity	X-Component	32
	Y-Component	32
	Z-Component	32
TBD	reserved	32
Total PDU Size		256

Chart 2: ETE E-8C ESPDU composition

The E-8C aircraft transmits a 1 Hz state message from the ANIU to the GNIU denoting its existence, location, and velocity. The GNIU translates this into an E-8C ESPDU and broadcasts over the DIS network. This information permits the aircraft to be visible to other players in the DIS environment.

This results in the following transmission bandwidth requirements.

		entities / sec	# entities	# bits	kbps
Uplink Messages, GNIU to ANIU	Max sustained rate	100		19,200	19.2
	10 min heartbeat rate	33	20,000	6,400	6.4
Downlink Messages, ANIU to GNIU	Joint STARS state message @ 1hz	1	1	256	0.26
Total RF link bandwidth requirements					25.86

Chart 3: Transmission Bandwidth

Available ETE RF bandwidth to the ETE is 19.2 kbps. Using a nominal compression ratio of 1.4:1, the required bandwidth is reduced to 14 kbps, which fits within capacity.

CONCLUSIONS

For an overhead stand-off system such as MTI or SAR radar, the DIS ESPDU can be drastically reduced in size and still provide the resolution and fidelity necessary to provide accurate sensor information for training exercises or developmental and operational testing and evaluation. Such a procedure can be applied to any sensor that cannot 'see' all the detailed information available in the DIS ESPDU. The combination of ESPDU stripping and update rate modifications allows a flying aircraft to participate in a realistic DIS exercise. These procedures can be used to bring together various real combat equipment linked over radio nets into a DIS simulation without the restrictions posed by limited RF bandwidths.

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